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Final Status Report

Testing the Pairs-Reflection model with X-Ray Spectral Variability and X-Ray Properties of Complete Samples of Radio-Selected BL Lacertae Objects

NASA Grant NAG5-2510

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Period Covered: February 1994 through May 1997

This is a final report to the National Aeronautics and Space Administration (NASA) concerning NASA grant NAG5-2510. This grant was awarded to Dr. C. Megan Urry of the Space Telescope Science Institute in response to two successful ADP proposals to use archival Ginga and Rosat X-ray data for "Testing the Pairs-Reflection model with X-Ray Spectral Variability" (in collaboration with Paola Grandi, now at the University of Rome) and "X-Ray Properties of Complete Samples of Radio-Selected BL Lacertae Objects" (in collaboration with then-graduate student Rita Sambruna, now a post-doc at Goddard Space Flight Center). In addition, post-docs Joseph Pesce and Elena Pian, and graduate student Matthew O'Dowd, have worked on several aspects of these projects.

The grant was originally awarded on 3/01/94; this report covers the full period, through May 1997.

We have completed our project on the X-ray properties of radio-selected BL Lacs. Published papers include:

- "X-Ray Properties of a Complete Sample of Radio-Selected BL Lacertae Objects" 1995a, C. M. Urry, R. M. Sambruna, D. M. Worrall, R. I. Kollgaard, E. Feigelson, E. S. Perlman, and J. T. Stocke, ApJ, 463, 424-443
- "On the Spectral Energy Distributions of Blazars" 1996, R. M. Sambruna, L. Maraschi, and C. M. Urry, ApJ, 463, 444-465

- “Spectral Variability of the X-ray Bright BL Lacertae Object PKS 2005-489” R. M. Sambruna, C. M. Urry, G. Ghisellini, and L. Maraschi, 1995, ApJ, 449, 567-575

While my post-doc, Joe Pesce, was supported by this grant, he published the following refereed papers:

- “Multi-Wavelength Observations of 3C 273 in 1993-1995” C. von Montigny, H. Aller, M. Aller, F. Bruhweiler, W. Collmar, T. J.-L. Courvoisier, P. G. Edwards, C. E. Fichtel, A. Fruscione, G. Ghisellini, R. C. Hartman, W. N. Johnson, M. Kafatos, T. Kii, D. A. Kniffen, G. G. Lichti, F. Makino, K. Mannheim, A. P. Marscher, B. McBreen, I. McHardy, J. E. Pesce, M. Pohl, E. Ramos, W. Reich, E. I. Robson, K. Sasaki, H. Teräsranta, M. Tornikoski, C. M. Urry, E. Valtaoja, S. Wagner, and T. Weekes, 1997, ApJ, 483, 161
- “Variability of the Ly α Emission Line in 3C 279” A. Koratkar, J. E. Pesce, C. M. Urry, and E. Pian, ApJ, submitted
- “Redshifts of Southern Radio Galaxies” 1995, R. Scarpa, R. Falomo, and J. E. Pesce, A&A, in press
- “Host galaxy and environment of the BL Lacertae Object PKS 0548-322: Observations with subarcsecond resolution” 1995, R. Falomo, J. E. Pesce, and A. Treves, ApJ, 438, L9
- “Environmental Properties of BL LAC Objects” 1995, J. E. Pesce, R. Falomo, and A. Treves, AJ, 110, 1554

While my post-doc, Elena Pian, was supported by this grant, she worked on the following refereed papers:

- “Multiwavelength Monitoring of the BL Lacertae Object PKS 2155-304 in May 1994. II. The IUE Campaign” 1996, E. Pian, C. Megan Urry, A. Treves, L. Maraschi, S. Penton, J. M. Shull, J. E. Pesce, P. Grandi, T. Kii, R. I. Kollgaard, G. Madejski, H. Marshall, W. Wamsteker, A. Celotti, T. J.-L. Courvoisier R. Falomo, H. H. Fink, I. M. George, and G. Ghisellini, 1997, ApJ, 486, in press
- “Multiwavelength Observations of a Dramatic High Energy Flare in the Blazar 3C 279” A. E. Wehrle, E. Pian, C. M. Urry, et al., 1997, ApJ, submitted

The following invited review papers and/or book chapters were based in part on work supported by this grant:

- “Variability of Active Galactic Nuclei” M.-H. Ulrich, L. Maraschi, and C. M. Urry, 1997, ARAA, 35, 445-502

- “Blazars, the Most Violent Active Galaxies” C. M. Urry, 1996, AAAS Annual Meeting and Science Innovation Exposition, 162nd National Meeting of the AAAS, ed. Michael S. Strauss, et al., p. S-48
- “An Overview of Blazar Variability” C. M. Urry, 1996, in *Blazar Variability*, (Proc. Conference in Miami, February 1996), ed. J. Webb

Finally, the following papers have been presented at or submitted for conferences:

- “The Large-Scale Environments of Radio Galaxies and BL Lacertae Objects” J. E. Pesce, M. O’Dowd, R. Scarpa, C. M. Urry, R. Falomo, J. Kim, and A. Paske, 1996, BAAS, 28, 1285 (#10.01)
- “The Broad Band Energy Distributions of a Complete Sample of Radio-selected BL Lacertae Objects” R. M. Sambruna, C. M. Urry, L. Maraschi, and G. Ghisellini, 1995, BAAS, 26, 1466
- “Rosat Observations of a Complete Sample of Radio-Selected BL Lacertae Objects” C. M. Urry, R. M. Sambruna, J. Stocke, E. Perlman, R. Kollgaard, E. Feigelson, D. Worrall, and P. Padovani, 1994, in *The Multi-Mission Perspective* (High Energy Astrophysics Division Meeting of the American Astronomical Society, Napa Valley, November 1994), p. 105
- “The Multifrequency Spectra of Blazars” R. M. Sambruna, C. M. Urry, L. Maraschi, and G. Ghisellini, 1994, in *The Multi-Mission Perspective* (High Energy Astrophysics Division Meeting of the American Astronomical Society, Napa Valley, November 1994), p. 106
- “ROSAT PSPC Observations of Radio-Selected BL Lac Objects” R. M. Sambruna, C. M. Urry, J. Stocke, E. Perlman, R. Kollgaard, E. Feigelson, D. Worrall, P. Padovani, L. Maraschi, and A. Treves, 1993, BAAS, 25, 1449
- “X-Rays and Relativistic Beaming in Radio-Selected BL Lacertae Objects” R. I. Kollgaard, E. D. Feigelson, D. C. Gabuzda, R. Sambruna, and C. M. Urry, 1993, BAAS, 25, 1449
- “PSPC Observations of the 1 Jy BL Lacs” R. M. Sambruna, C. M. Urry, J. Stocke, E. Perlman, R. Kollgaard, E. Feigelson, D. Worrall, P. Padovani, L. Maraschi, and A. Treves, 1993, in *The Soft X-Ray Cosmos*, ed. E. M. Schlegel and R. Petre, (College Park: AIP Conf. Proc. 313), p. 415
- “X-Rays and Relativistic Beaming in Radio-selected BL Lacertae Objects” R. I. Kollgaard, E. D. Feigelson, D. C. Gabuzda, R. M. Sambruna, and C. M. Urry, 1993, in *The Soft X-Ray Cosmos*, ed. E. M. Schlegel and R. Petre, (College Park: AIP Conf. Proc. 313), p. 420

- “Star Formation in Normal and Barred Cluster Spirals” 1995, C. Moss, M. Whittle, J. E. Pesce, and H. Navaro, *Astrophysical Letters and Communications*, 31, 215
- “The cluster environment of BL Lac Objects” 1994, R. Falomo, J. E. Pesce, ESO Messenger, 78, 30

Funds from this grant have been used to support post-doc and graduate student salaries, as well as their travel to scientific meetings to present the results as listed above.

With respect to the project on testing the pairs-reflection model, Paola Grandi has completed and/or published a number of papers:

- “Rosat, ASCA, and OSSE Observations of the Broad Line Radio Galaxy 3C 120” P. Grandi, R. M. Sambruna, L. Maraschi, G. Matt, **C. M. Urry**, and R. F. Mushotzky, 1997, ApJ, in press
- “High Energy Break and Reflection Features in the Seyfert Galaxy MCG+8-11-11” P. Grandi, F. Haardt, G. Ghisellini, E. J. Grove, L. Maraschi, and **C. M. Urry**, 1997, ApJ, submitted
- “Detection of a High Energy Break in the Seyfert Galaxy MCG+8-11-11” P. Grandi, F. Haardt, G. Ghisellini, E. J. Grove, L. Maraschi, and **C. M. Urry**, 1997, in *Proc. 4th Compton Symposium* (Williamsburg, April 1997), in press
- “The High Energy Spectrum of the Radio Galaxy 3C 120” P. Grandi, R. Sambruna, L. Maraschi, **C. M. Urry**, and R. F. Mushotzky, 1997, in *X-Ray Imaging and Spectroscopy of Cosmic Hot Plasmas*, eds. F. Makino and K. Mitsuda (Tokyo: Universal Academy Press), pp. 283–284
- “The X-Ray Spectrum of 3C120: An ASCA Observation” P. Grandi, R. F. Mushotzky, L. Maraschi, **C. M. Urry**, and T. Ohashi, 1994, in *The Multi-Mission Perspective* (High Energy Astrophysics Division Meeting of the American Astronomical Society, Napa Valley, November 1994), p. 109

FINAL PATENT/INVENTION REPORT

Grant: NAG5-2510

Principal Investigator: Dr. C. Megan Urry

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Patents/Inventions Developed: NONE